Global Scientific JOURNALS

GSJ: Volume 11, Issue 8, August 2023, Online: ISSN 2320-9186

www.globalscientificjournal.com

THE DESIGN, PRODUCTION, AND TESTING OF AN AUTOMATIC VALVE-BAG RESUSCITATOR.

Odor Godwin Ekunke and Ebieto Celestine Ebieto

ABSTRACT: The world was being plundered with the deadly Corona Virus, popularly called Covid-19, with over 6,630,082 death cases, and the crippled global economy with a loss of over $5 trillion. In response to these global challenges. The Food & Drug Administration of the U.S. had allowed open-source access to the general public through Emergency Use Authorizations (EUAs) to contribute efforts to curb the ravaging negative effects of Corona virus and associated complications. Authorities having professional jurisdiction to involve in the production and supply of ventilators, resuscitators, its accessories and also to provide potent measures capable of restoring respiratory disorders, which are integral tools in the treatment of breathing issues in the Covid-19 era. This study under the Emergency Use Authorization and Resuscitator aimed to design, produce, and test an automatic valve bag resuscitator as a Non-Rebreathing Device. The device used positive pressure aeriation (ventilation) as the working principle. Arduino Nano module was used as a design platform to obtain Results data like the, breathing rate of 10-12bpm, inspiration time of 1-2s, max. inspiration pressure of 15-40cmH2O, expiration time 2-3s, tidal volume of 6-8ml for children and 390-520ml for adult, a delay time of 2-5s. This is an innovative work to be used as a lifesaver, test requirements appropriate to support safe operation were identified and adhered to.

KEYWORDS:

Asphyxiation, Delay Time, Tidal Volume, Fraction of Inspired Oxygen (FiO_2), Insufflation.

INTRODUCTION

1.1. Background

In response to the rampaging global pandemic of Corona Virus (Covid-19), its deadly effects or negative impacts on human race and global economy. Emergency Use Authorizations (EUAs) has been granted by the U.S Food & Drug Administration (FDA) to the general public to contribute in one way or the other to curb the ravaging virus, that is. (Fischer, 2020) FDA issued EUAs to Institutions, private or public professionals (Authorities having jurisdiction) Authorities having professional jurisdiction to get involved in the production and supply of ventilators, resuscitators, its accessories capable of restoring respiratory disorders, which are integral tools in the treatment respiratory disorders in the Covid-19 era.

Having made a researched on The Public Availability (open sourcing) of Ventilator software and Design, also having attended the Pandemic Engineering Training on Ventilator, Resuscitator Assembly & Design hosted by Worcester Polytechnic Institute U.S.A. I considered this as an opportunity to made a research on the design, production, and testing of a Valve Bag Resuscitator, to be used in the University of Port Harcourt Health Center. This work was designed according to the requirement granted through the US Food & Drug Administration (FDA) on Emergency Use Authorization (EUA).

Though, the FDA enlightens you how to think and come up with creative ideas, but in general it doesn't tell you exactly the procedures or the tasks to embark on, you have to essentially show that you have the good rational for what you selected to design and produce, also for what you choose as a requirement and one will be apt sure that you actually met those requirements.

Criteria for Safety, Performance and Labelling of EUA (2020) stated the requirements for a product under FDA permission.

1.1.1. Definition of a Resuscitator

A resuscitator can be defined as a medical device that uses positive pressure to expand or pump up the unconscious person's lungs, or someone who is unable to breathe, so as to supply oxygen for their survival and quick recovery back to normal breathing.

There are three primary types of resuscitator, there are:

I. Manual version (otherwise called a bag-valve mask) consisting of a mask and a large hand-squeezed plastic bulb using ambient air, or with supplemental oxygen from a high-pressure tank.

II. Another type is the Expired Air or breath powered resuscitator. Appearance of the second kind is like the Brooke Airway introduced in 1957.

III. The third type is an oxygen powered resuscitator. These devices functions with a pressurized gas supplied through a regulator, they are either controlled automatically or manually controlled. This kind is the type discussed in this work having the automatic features functionalities.

1.1.2. Resuscitators Information

Resuscitators are medical devices that use positive pressure to manually respirate patients who have compromised breathing. Lungs expel the air due to their natural elasticity. These devices are typically used temporarily until the patient can be transferred to a medical ventilator. Resuscitators are much smaller in size compare to ventilators, this make them more effective for emergency medical treatment.

According to safeopedia: A positive pressure is one that is greater than the ambient pressure in any given environment, chamber, room, or confined place. A closed zone is maintained under continual positive pressure to prevent the entry of any contaminated gaseous or liquid from the outside.

2. LITERATURE REVIEW

2.1 Early Development of the Science of Resuscitation and Resuscitator

Basically, a resuscitator was developed as a result of the quests by scientists and philosophers to overcome the past dogma belief, that it is only God who has the power to reverse sudden death or death generally. From the time immemorial, resuscitation was forbidden and prohibited by humans. At some point people made a shift in this belief that apart from God, the prophets also have the spiritual ability to raise death people as recorded in 2King 4:34 (Bible, 1200 BC) where the first type of resuscitation of mouth-to-mouth was practiced.

In 1750, this dogma was challenged by a group of scientists and philosophers during an amazing scientific discovery. Here (Eisenberg, History of the Science of Cardiopulmonary Resuscitation, 2010) pointed that, Scientists and philosophers believe human beings could understand and control their own destinies. Therefore, the science of resuscitation is believed to begin where science itself began. This was made realistic through scientific method and most importantly the Enlightenment of the mind. Through experiment and swirling discoveries of the Enlightenment, there was a belief that if people could study and understand life, then there are possibilities of reversing death. The first case moves to handle the issues of sudden death through drowning was in 1700s in large port cities of the Europe. Here religion was no longer seen as the only life-saving means. The Amsterdam Rescue Society was founded in 1767, as a humanity earnest collective effort and desire to attempt the resuscitation of sudden death. And within a year 400 casualties got documented by drowning alone, the Rescue Society claimed to have saved about 150 persons from watery death.

In 1774, The Royal Human Society was founded in London, the society emblem shows an iconic angel blowing on an ember (coal) and with Latin inscription which translate as thus; ‘‘A little spark may yet lie hid’’ a wonderful metaphor of a prevailing belief which literally mean that provided there is warmth in the body, life could still be reignited. Again, the will and passion to resuscitate came as a result of the Enlightenment.

2.1.1. Mouth-to-Mouth Resuscitation: The Mouth-to-mouth resuscitation (MTMR), It is defined as man-made emergency ventilation , is the act of assisting or stimulating respiration. Here the rescuer presses their mouth against that of the victim and blows air into the person's lungs. Artificial respiration is carried out in different forms, but generally means providing air for a patient that cannot breath by himself/herself or is not producing enough respiratory force by themselves. It is administered on a patient with a breathing heart or as a form of cardiopulmonary resuscitation (CPR) to get the heart into normal or partial respiration (Encyclopedia, 2007).

External respiration (and hence Pulmonary ventilation) is done via manual insufflation by the lungs either via the rescuer pumping air from his mouth into the victim's lungs, or via the mechanical device to achieve it. It is also referred to as the kiss of life, rescue breathing, expired air resuscitation, and expired air ventilation. The term was introduced in 1950.

The majority of CPR protocols include mouth-to-mouth resuscitation (cardiopulmonary resuscitation). It being a crucial ability for first aid. Mouth-to-mouth resuscitation is sometimes done separately, such as in cases of opiate overdose and neardrowning. Most procedures currently only allow medical experts to perform mouth-to-mouth resuscitation on their own, while lay first-aiders are instructed to perform full CPR whenever a patient is not breathing enough (Stathis Avramidis, 2012).

Figure 2.1 Mouth-to-mouth Resuscitation

Insufflation: is the process of forcefully pushing air into a victim's respiratory system. It is often referred to as "rescue breaths" or "ventilations." Numerous approaches can be used to do this, depending on the circumstances and tools at hand. All techniques necessitate appropriate airway management, which guarantees the technique's efficacy. These techniques consist of:

1. Mouth-to-mouth and nose: Used on newborns (often up to one-year-old), this type, the seals are the most effective.
2. Mouth-to-mouth: In order to breathe air into the patient's body, the rescuer must create a seal between his or her mouth and the patient's mouth.
3. Mouth-to-nose - The rescuer might occasionally need to or want to create a seal with the patient's nose. The most common causes of this are maxillofacial injuries, conducting the treatment while submerged in water, or having vomit residue in the mouth.
4. Mouth-to-mask: To lower the risk of cross infection, the majority of organizations advised using a barrier between the patient and the rescuer. The "pocket mask" is one such variety. Compared to a Bag Valve Mask, this might be able to produce higher tidal volumes.

2.2 Advances on the way of Resuscitation

Many methods of resuscitation were adopted and these include; placing a victim on a barrel and rolling him to and fro while holding up his legs, this method allowed the abdomen of the victim to be squeezed which allow small amount of air to reach the lungs. Another method was through the application of bellow to blow air into the victim's mouth where some of the air goes into the stomach or to the nose. Also, tobacco smoke was used to insert into a drowning victim, seeing that it serves as a stimulant and people taught smoke could revive an unconscious person, sincerely, all these methods were just mere common sense without scientific proofs or backings. Between 1767 to 1949 there were more than hundreds of methods and techniques recommended for artificial ventilation, some of them relied on direct pressure to the abdomen, back, and chest. The originators of these methods thought that passive supply of oxygen to the lungs was enough to get adequate oxygenation. Actually, these techniques were not very effective, and it was surprised to know that all these methods were not propounded by scientists. And also, no scientist supported the mouth-to-mouth method of respiration. This was because a popular belief that spanned over many decades as of then, that the expired air does not contain enough oxygen to sustain life.

(Mcadams, 2008) Stated clearly the techniques for newborn resuscitation, the principle in this article was what made James Elam to proselytize the mouth-to-nose respiration, that exhaled air was adequate to oxygenate non-breathing person. (Elam & Safar, 1977) In a joint effort reiterated through experiment that the mouth-to mouth resuscitation was effective and that the expired air contain enough oxygen. Hence the official documentation and acceptance of the method was established.

(Jantti, 2010) The chest compression method of resuscitation was discovered by William Kouwenhoven, Guy Knickerbocker, and James, and was first used to revive an obese woman who had a cardiac arrest in 1960. The Chest compression, external massage, mouth-to-mouth was combined into what we called Cardiopulmonary Resuscitator (CPR). Hence CPR that is practiced today was developed in 1960. (Eisenberg & Psaty, Cardiopulmonay Resuscitation, 2010).

(Jude, 2003) Dr. C. Beck, a cardiac surgeon in 1947 discovered the Ventricular defibrillation, that is; the stopping of the heart from fibrillation or irregular contractions in order to restore it using electric shock, he is referred to as the father of modern surgery. He applied this technique successfully to revive a 14-year old boy with the open-chest massage and internal defibrillation. Henceforth the scientist, Beck kept improving his model with series of experiments to enhance the efficiency of the machine. Subsequently, these models were designed for open-heart defibrillation, he modeled it in such a way that it could perform both shock and massage. Suction cups were attached to the heart wall and other alternating suction would expand and allow the heart to relax, and this machine was able to massage at a rate of 129 beats per minute, relieving the surgeon of performing the massage.

External defibrillation (Zoll, 2002), in 1950, Paul M. Zoll (see fig 2.2) developed the external pacemaker to stimulate the heart across the chest, the pacemaker was operated using line current with a maximum voltage of 150 volts. The output and rate voltage was controlled from the face of the pacemaker. It has two electrodes where one is placed at the right and the other at the left chest, they were held in place by a rubber strap and making contact via a conductive electrode jelly. The electrodes were two one-inch diameter disc. In 1952 Zoll published his work for the first on the revolution and advancement on the concept of resuscitation of the patients with heart obstruction and asystole. To stimulate an adult heart, it requires about 100 volts.

Figure. 2.2: Zoll Pacemaker defibrillation

2.3. Cardiopulmonary Resuscitation (CPR)

In the late 1950s, there was revolutionary development of fundamental knowledge, techniques, teaching, and practice of cardiopulmonary resuscitation (CPR) have resulted in the saving of uncountable lives from conditions that previously led to certain deaths. By the 1950s also, there was a major breakthrough in respiratory resuscitation, in the 1960s, breakthroughs in cardiac resuscitation, and in the 1970s have begun to show breakthrough in resuscitation of the arrested brain. There a was mobilization of large-scale public involvement in life-saving efforts. But the quest for of implementing new knowledge in CPR on a large scale has brought agencies and politics into the field, unnecessarily complicating initially clear concepts and simple techniques that simple understanding and collaboration would have solved, got worst. (KOUWENHOVEN, 1977).

Surviving a cardiac seizure depends on a sequence of time- sensitive interventions. The concept of the original chain of survival emphasizes that each time - sensitive intervention must be optimized in order to maximize the chance of survival (Nolan, 2005): it is often said the "chain is only as strong as its weakest link". That is, the little area of a sequential events is as important as the whole events combined together.

2.3.1. Definition and Discussions on Cardiopulmonary Resuscitation (CPR)

Cardiopulmonary resuscitation (CPR) is defined as a lifesaving technique or means. Its aim is to make sure blood and oxygen are flowing through the body when a person's heart and breathing have stopped.

Also, according to The (Center for Disease Control and Prevention, 2021); Cardiopulmonary resuscitation (CPR) is an emergency procedure that can help save a person's life if their breathing or heart stops.

2.3.3. Types of Cardiopulmonary Resuscitation

There are two different methods of CPR, and each of them have the ability to save lives. These include:

1. **Hands-only CPR:** Involves calling for assistance while initiating the chest pushing of the victim in a rapid motion. These up and down actions are known as chest compressions. This type has a potential to getting the flow of blood faster in and around the body.
2. **Cardiopulmonary Resuscitator with breaths:** the cardiopulmonary Resuscitation with breaths, this switches between chest compressions and mouth-to-mouth breaths. In the crucial seconds before aid arrives, this form of CPR can provide the body with extra oxygen for fast survival response.

2.3.4. The Chain of Survival

The actions linking the victim of sudden cardiac arrest with survival are called the Chain of Survival. They include early observation of the emergency and deployment of the emergency services, immediate CPR, immediate defibrillation and early application of advanced life support. These chain of events are expatiated below:

Figure 2.3.4. Chain of Survival.

a. **Early recognition and call for help to prevent cardiac arrest** : this states the importance of recognizing patients who are susceptible to cardiac arrest, quickly calling for assistance and also providing effective treatment to hopefully prevent cardiac arrest; research has shown that up to 80% of patients sustaining an in - hospital cardiac arrest have displayed signs of deterioration prior to collapse, most patients sustaining an out - of - hospital cardiac arrest also display warning symptoms for a significant duration before the event.

b. **Early CPR to buy time and early defibrillation to restart the heart**: the two-central links in the chain stresses the importance of connecting CPR and defibrillation as essential components of early resuscitation process in an attempt to restore the victim back to life.

c. **Post - resuscitation care to reinstate quality of life**: the priority is to preserve cerebral and myocardial function, to bring back quality of life and indicates the potential benefit that may be provided by therapeutic hypothermia. Remember the best post-resuscitation therapy is the BOLT therapy ((Odor Godwin E, 2022), which seeks to restore the breathing volume of the individual to avoid any future arrest.

3. DESIGN METHODOLOGY

3.1. Research Area:

This study is solely designed to solve the problem of Asphyxiation, a medical issue. As a result of a loss or insufficiency of oxygen in the brain, this is known as the failure or perturbation of the respiratory process. This usually results in an unconsciousness that sometimes leads to mortality.

The study provides two solutions. Solution one is focused to remedy the problem with the design of a resuscitator to restore breathing to an individual suffering from respiratory disorder. e.g. covid-19 situation, athletics or domestic cardiac arrest.

System Description

3.2.1. Automatic Valve Bag Resuscitator

Automatic valve-bag resuscitator is a ventilation device that squeezes oxygen into the lungs of the patient with compromised breathing functions due to cardiac arrest or severe respiratory malfunctions.

This device operates on the PPV (positive pressure ventilation) principle, which explains the practice of either utilizing a nose mask or, more often, a ventilator to provide breaths and reduce a critically ill patient's labor of breathing (Potchileev, Doroshenko, & Mohammed., 2021).

Positive pressure ventilation is administered in two ways:

I. Non-invasive positive pressure ventilation: This occasionally requires wearing a mask,

II. Invasive positive pressure ventilation: Here a tracheostomy tube or an endotracheal tube must be used to supply breaths during respiration. The inter-professional team members handling the treatment of seriously sick persons that need positive pressure ventilation were made aware of the physiological signals, contraindications, and any other important variables during this activity. (Winters, Bond, DeBlieux, Marcolini, & Woolridge, 2017).

There are four components of positive pressure ventilation: These include:

I. Pressure of the ventilated air that flows in and out of the lungs.

II. Quantity of the inspired air taken in and expired air out of the lungs.

III. Proportion of air rush into the lungs.

IV. The inspiratory and expiratory time.

Mathematical expression of Positive Pressure

Technically speaking, the changes in pressure, volume, and flow that occur at inspiration, and when expiration are used to describe a breath during PPV. A straightforward equation is normally used to quantitatively define these concepts:

$$P = P1 + (R\ ) + (Vt + Ee) \qquad (3.1)$$

Where P1=initial alveolar pressure, P = airway pressure, Vt = tidal volume, R = resistance to flow, Ee = inherent Elastance of the pulmonary system.

P1 is the alveolar pressure normally occurred at the start of inspiration. This figure may be atmospheric pressure in a person who is not mechanically ventilated. (=760 mm Hg or 101.325K Pa), or more than atmospheric pressure in the case of PPV (>760 mm Hg or 101,325 Pa).

3.3. Research Design

Design methods were used to designed the Resuscitator according to specification to meet the design intents.

3.3.1. Design Intent:

I. To design an effective Resuscitator device that has the capacity to revive a patient whose respiratory function has been compromised or lost due to Covid-19 complication, Cardiac arrest, or any respiratory related issues.

3.3.2. Design Methods.

The design methods used for the work are based on the approaches that effectively yielded proactive result towards actualization of the design intent.

I. **Method 1:**

Adoptive Design: I used both existing and latest scientific principles and technical information that has been deployed in other developed countries for tackling Covid-19 and Respiratory issues, to design and model the device with suitable modification/changes

II. **Method 2:**

Development Design: I incorporated the modifications in shape, sizes, forms, material, and power ranges of the device's components such as oxygen sensor and the circuit parts to suit the design intent for the device. This type requires considerable scientific training and design abilities.

3.3.3. Design Specification for Materials:

1. Electric Motor

Type	DC Motor
Voltage:	12 Volt
Weight:	0.09kg
Material	Steel Metal
RPM	6-10RPM

This is convenient for Arduino functions as the direction of rotation can be easily configured. And Arduino has a maximum current tolerance of **5volt**.

2. Rechargeable Battery

Type: Genesis lead-gel battery completely sealed high-performance,

Current: 13A

Voltage: 12V

Dimensions: 70 x 60 x 100 mm

Weight: 4.9 kg

Time to discharge when fully charge:4 hours

It can be fixed in any position and has excellent resistance to vibration.
Range of operating temperatures much wider than the other batteries (-40° + 80 ° C)

Technical Specifications:

High discharge speed
Suitable for long stand-by
Very high energy density
Service life: 10 years at 20 ° C (68 ° F)
Excellent cyclic capacity, 400 cycles at a discharge depth of 80%
Low self-discharge. (Aliveneta, 2022)

3. Arduino Nano

I. Arduino's classic breadboard, a responsive circuit board with small dimensions. Often time have a pinhead for fast connection with the breadboard and presents a Mini-B USB connection port.

II. Why is it used? It's a perfect micro controller to learn interesting electronics and can be reprogrammed, and its size makes it excellent for building into projects which require a small form factor. In the world of computer technology, the size, design, or physical arrangement of a computing device is referred to as its form factor. Nano type of Arduino is a small, complete, and breadboard-friendly, the board based on the ATmega328P released in 2008.

III. There is a ATmega328, it is a microcontroller, and a 16 MHz clock speed automatic-reset ability.

IV. We used Arduino Motor Driver Shield. This allows the Arduino board to interface with driver of a motor DC.

V. It has a voltage tolerance of 5Volt.

3.3.4. Design Processes.

The following design processes were fully deployed for effective design, modeling (prototyping) production and testing of Automatic Valve Bag Resuscitator (Jia, 2005)

1. Identification of Need
2. Background Research
3. Goal Statement
4. Task Specification
5. Synthesis
6. Analysis
7. Selection
8. Detailed Engineering Design
9. Prototyping and Testing
10. Production

3.4. Methods of Data Collection

The data for this research work were collected and gathered from the modules that were used to designed and assembled the resuscitator.

The Electronic segment of the Resuscitator can be sub divided into sub-functions as follows;

1. The input Module: The Arduino Circuit Board, Acrylic material, Valve-Bag, 13A 12v Battery
2. Sensor-Input Module: The oxygen Sensor
3. Processing Module: Potentiometer, Microcontroller
4. Display Module: 2x20 LCD
5. Control Module: 12V 13 A DC Motor, H-bridge driver circuit,

3.5. Design Components:

The following are the list of materials used for this research study.

Device Components

1. Arduino Nano
2. Liquid Crystal Display Module
3. 10k Potentiometer
4. Voltage Divider
5. L298n Motor Driver Circuit
6. 12v DC Motor
7. 13A 12v Battery
8. Voltage Regulator
9. Blood and Oxygen Sensor
10. Light Emitting Diodes
11. Valve Bag
12. Acrylic board

3.5.1. Working Principle

The 12v DC Motor is connected to the first terminal of the LZ98N motor driver, it rotates after receiving power from the internal dual H-bridge directional switching circuit possessed by the L298N motor driver, the H-bridge circuit receives input signals from the digital pins of the Arduino Nano micro-controller. A delay is added to vary the frequency of the shaft rotation which is extended to press the respiratory valve bag. The delay is alternated by the micro controller. This alternation in delay is attributed to the input received from the potentiometer which is connected to the analog pin of the Arduino Nano micro controller. This input varies on the rotation of the knob of the potentiometer. The potentiometer is a voltage divider and each Knob rotation divides a Known voltage by a *certain resistance value. The resistance value is read and inputted as the delay for the rotation of the shaft of the DC motor by the Arduino Nano micro controller. See circuit diagram below in figure 3.3*

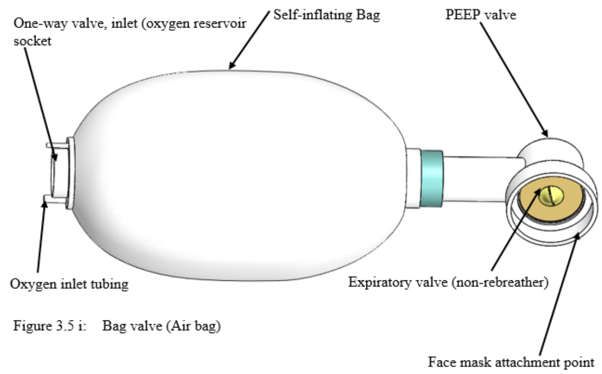


Figure 3.2 Valve Bag

Bag Valve mask: A bag valve mask (BVM), also referred to as a hand operated or mechnical resuscitator or "self-inflating bag" or by the trademarked name Ambu bag**.** Is a portable device that is frequently used to give patients who aren't breathing or aren't breathing enough positive pressure ventilation. As a piece of normal tool found on a crash cart, in emergency rooms, or in some intensive care units, the item is extensively utilized in hospitals. It is a necessary component of resuscitation equipment box for trained personnel in out-of-hospital situations such as ambulance crews. (Mabry & Frankfurt, 2011).

Specifications:

Bag valve is made of an opaque or clear or transparent elastic plastic.

With thickness = 1 mm.

Volume = 500 mL

Length = 250mm

How the Bag valve mask (BVM) works.

The BVM is made up of a face mask that is connected to a soft air compartment (the "bag," which is about a foot long) through a shutter valve. During the time the "bag" is released, from the squeezer arm rotation from the DC motor. In addition to permitting the person's lungs to flatten to the surrounding environment (not involving the bag), it self-pumps from its other end, carrying in either surrounding air or a low pressure oxygen flow delivered by a controlled cylinder. The apparatus forces air in the victim's lungs if the face mask is appropriately worn.

Uses of Bag Valve Mask:

The following are major uses of bag valve resuscitation (Nickson, 2020):

1. Provision of controlled ventilation

2. Provision of augmentation of spontaneous ventilation
3. Administration of high flow O2.
4. Provision of PEEP (positive end-expiratory pressure)

3.6 Design Tools

This study used the following design Tools:

1. Solidworks Design Software (3D Software):
2. Ultimaker Cura 4.6
3. 3D Printing Machine

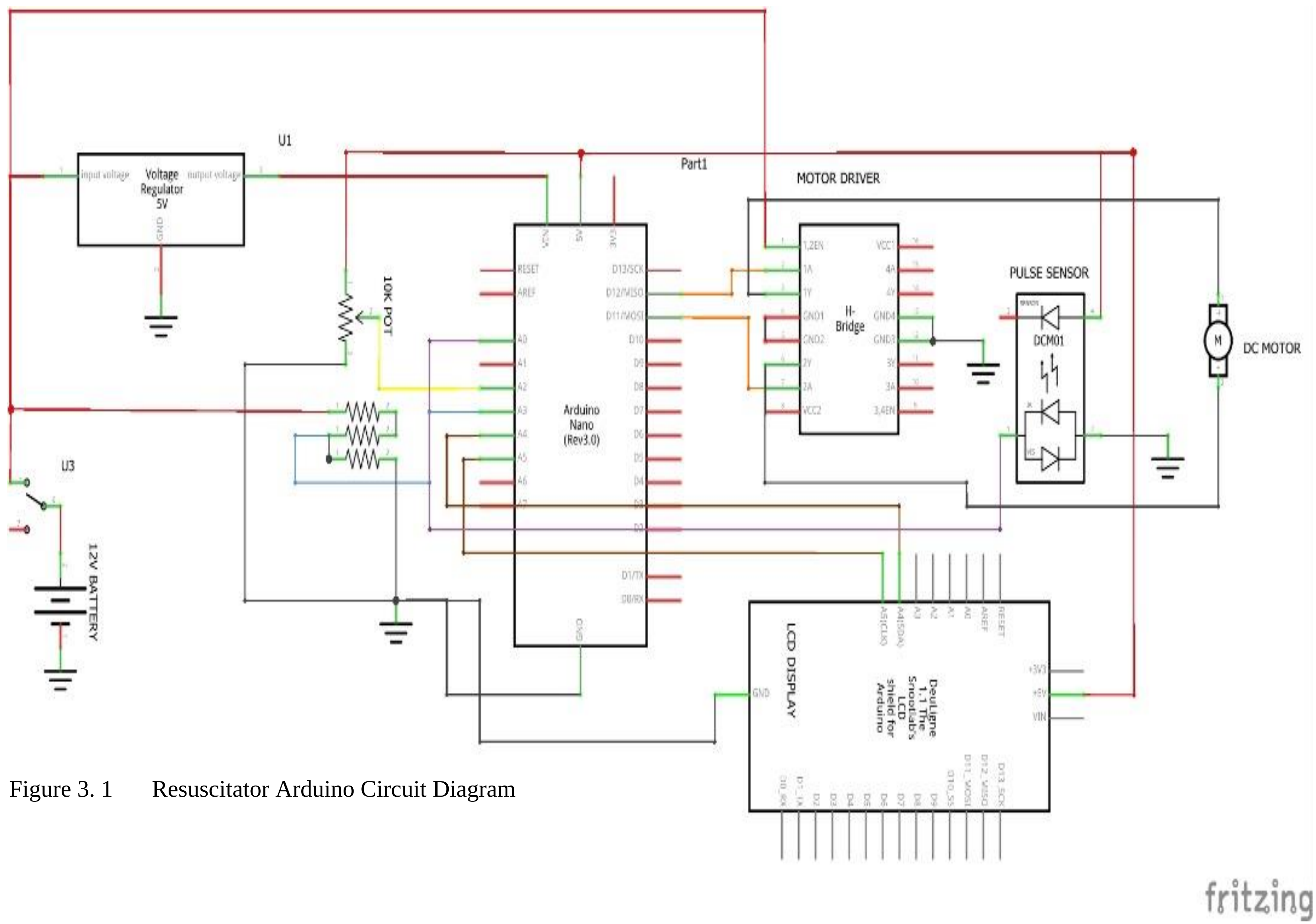
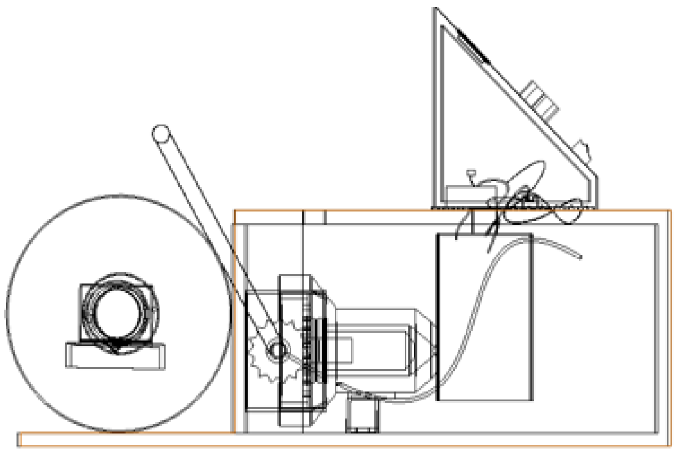


Figure 3. 1 Resuscitator Arduino Circuit Diagram



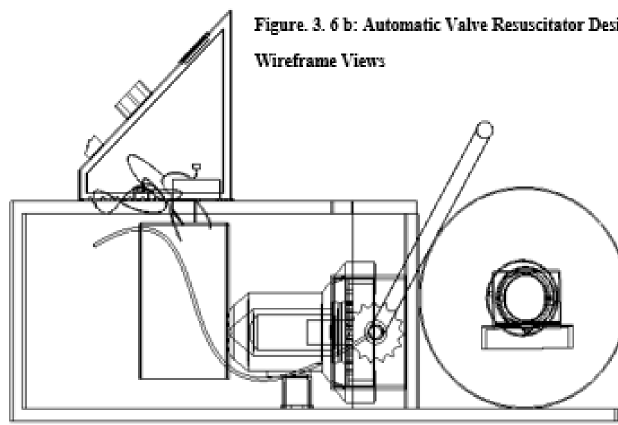


Figure. 3. 6 b: Automatic Valve Resuscitator Designs Wireframe Views

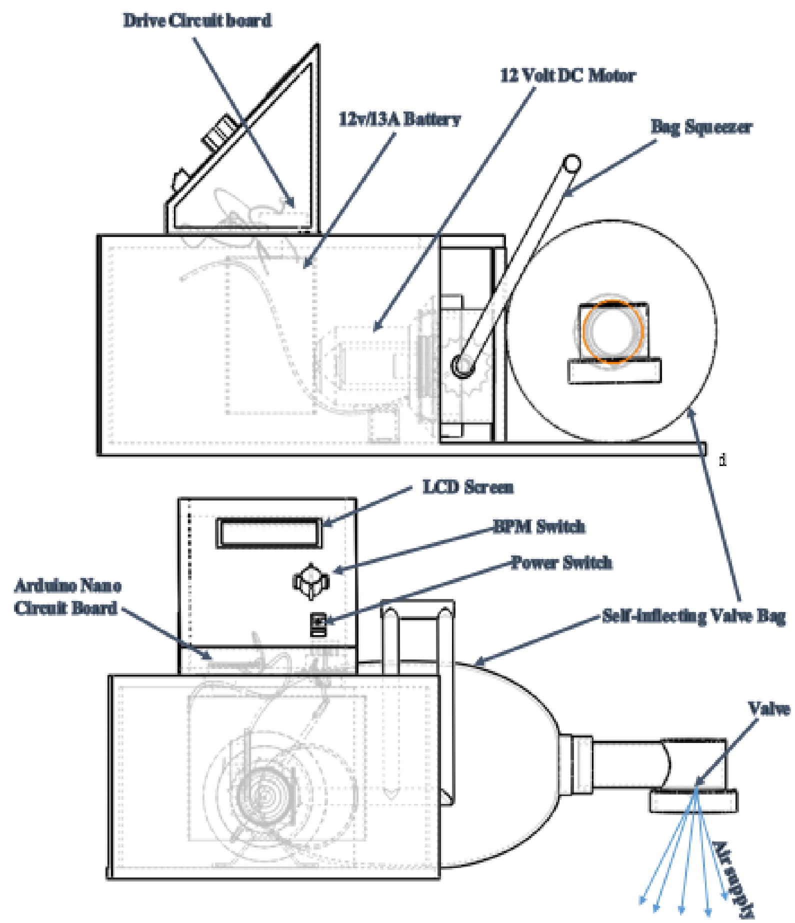


Figure 3. 6 c: Automatic Valve Resuscitator Designs Parts Labeling

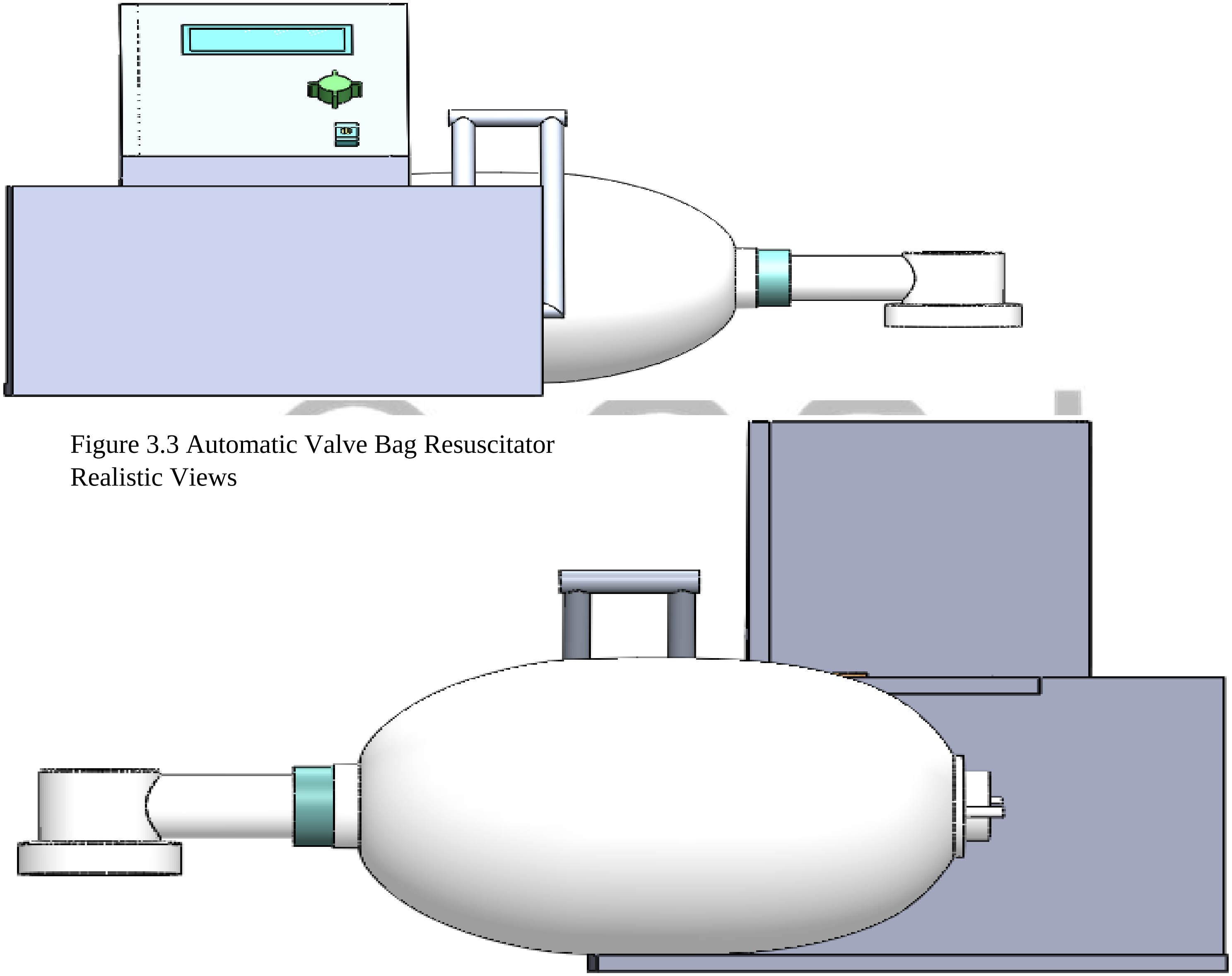
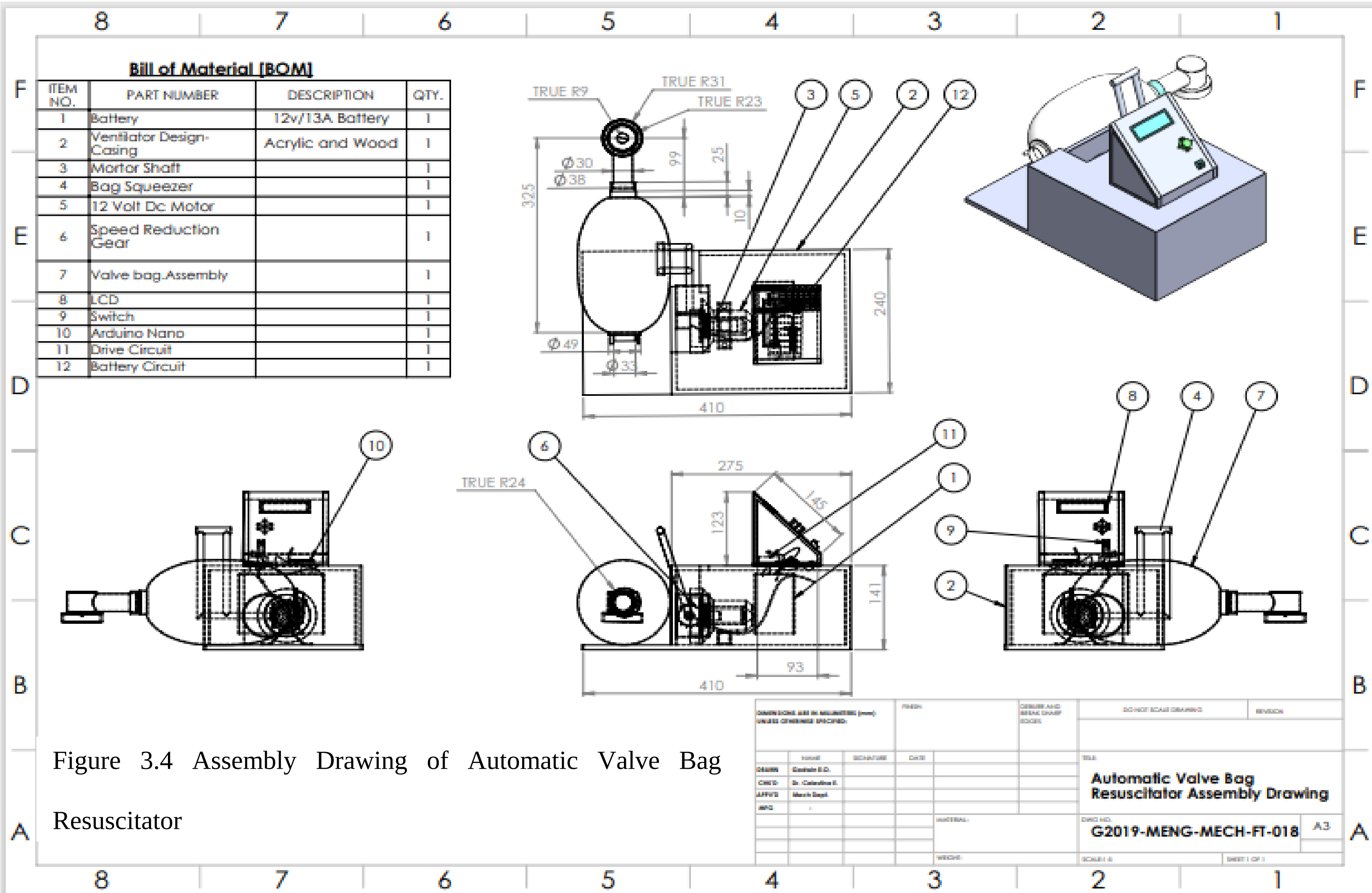


Figure 3.3 Automatic Valve Bag Resuscitator Realistic Views



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Battery	12v/13A Battery	1
2	Ventilator Design-Casing	Acrylic and Wood	1
3	Mortor Shaft		1
4	Bag Squeezer		1
5	12 Volt Dc Motor		1
6	Speed Reduction Gear		1
7	Valve bag Assembly		1
8	LCD		1
9	Switch		1
10	Arduino Nano		1
11	Drive Circuit		1
12	Battery Circuit		1

Figure 3.4 Assembly Drawing of Automatic Valve Bag Resuscitator

3.7. Experimental Calculations.

1. **Example 1.**

Using the Resuscitator with a Non-Rebreathing Mask (NRB) to Testing the efficiency

Here if you notice the Nasal Cannulae is not working effectively as to restore the patient breathing rhythm. we take it off and replace with the Non-Rebreathing mask. Her peak inspiratory flow is increased to **15** liters per minute.

Solution:

Given:

NRB flow= 15 l/m; NRB O_2 Concentration= 100%; Atm. Flow = 25 l/m;

Atm. O_2 Concentration = 21%; Peak Inspiratory Flow = 40 l/m

$$FiO2 = \frac{\text{NRB Flow x NRB O2 COnc} + (\text{Atm. Flow x Atm. O2 Conc}}{\text{Peak Inspiration Flow (PIF)}} \quad (3.7)$$

$$FiO2 = \frac{(15 \text{ x } 100) + (25\text{x } 21)}{40} = 50.6\%$$

on **15 liters** by a non-rebreathed mask and for the sake of this example we'll assume that her peaking spiritual flow rate remains at **40** liters per minute so by making this change you're able to deliver oxygen of about **15 liters** via the non-rebreathed mask and so she requires less air from the atmosphere to make up her requirement and so the FiO_2 goes up because the ratio of oxygen to atmospheric air has increased.

4. RESULTS AND DISCUSSIONS

4.1 Results

The results obtained from the Automatic Valve-bag resuscitator are presented in the table.

4.2. Result parameters obtained from the Resuscitator

Table 4.2. Respiratory Parameter obtained from the Resuscitator

Respiratory Parameters obtained from the Resuscitator			
S/N	**Measured parameter**	**Value**	**Unit of measurement**
1	Inspiration Time	1-2	second
2	Expiration Time	2-3	second
3	Inspiration Pressure	15-40	cmH_2O
4	Delay Time	2-5	second
5	The Tidal Volume	6-8 (Infants) & 390 – 520(Adult)	Milliliter
6	The ratio of I: E	1:1,1:2 & 1:4	-
7	Respiratory Rate	10-12	1/s
8	The volume of air per min	5000- 6000	Milliliter
9	FiO_2	100	%

4.3. Discussions of The Results for the device

Table 4.2 Represents the output parameters from the resuscitator and explained as thou:

I. **Inspiration Time**: The inspiration time is the time taken to deflect (supply) oxygen to the person's lungs of a patient. The time for inspiration is between **1-2 seconds.** Note; on inspiration (inhalation) the bag is deflected partially, while on expiration it is re-inflected fully. That is how it was designed to work. And it is called a Non-Re-Breather (NRB) valve bag, or self-inflected Bag.

II. **Expiration Time**: This is the time from beginning and end of one exhalation, this is in range of 2-3s.

III. **Inspiration Pressure**: this is the force exerted upon the unit area of the Bag as it pushes the FiO_2 (fraction of inspired oxygen) into the lungs of the patient. The optimum value for safe operation is between 15 to 40 cmH2O and adjustment is made in steps of 5 cmH2O

IV. **Delay Time:** This refers to the time delay between each inspiration. And is between 4-5 seconds.

V. **The Tidal Volume:** This is the volume delivered by the Resuscitator is between 6 to 8ml/kg of ideal body weight. For an adult with 65kg, the tidal volume is 390 to 520ml (ml= milliliter). This is delivered by adjustment of the device tidal volume in steps of no more than 50ml. Preferably a lower range of 250ml and an upper range of 600ml or 800ml. This refers to the amount of oxygen taken in during inspiration**.** the quantity of oxygen that the patient's lungs received on inspiration from the bag**.** The amount of air normally displaced between a regular inhalation and exhale in the lungs when no additional effort is made. Tidal volume for an over-breathing person is from 900ml and above. The volume of air we inhale and exhale is measured in liters, and measurements are usually taken over one minute. In conventional medicine, the accepted respiration rates a healthy person takes in one minute is 10 to 12, with each breath drawing in a volume of 500 milliliters. In a full minute, this provides the body with a total volume of 5 to 6 liters. If a person is breathing at a higher rate of twenty breaths, for example, then the volume will also be higher, and vice-versa. To visualize this amount of air, imagine how much air would be contained in a two-liters soft drink bottle.

VI. **Respiratory Ratio**: this refers to the ratio of the volume of FiO_2 inhalation to CO_2exhalation (I:E). Realistically, we exhale twice the inhale that is, 1:2 for normal breather, while 1:4 for over-breathing. But the ideal ratio is 1:1

VII. **Respiratory Rate:** The number of breaths an individual takes each minute is known as his respiratory rate. Adults typically breathe between 12 and 20 times per minute while at rest. At repose, breathing more than 25 times per minute or less than 12 breaths per minute is seen as abnormal.

VIII. **Volume (Amount) of air per minute:** This refers to the quantity of air drawn into your lungs with each breath. The volume of each breath of air we inhale and exhale is measured in liters, and measurements are usually taken over 1 minute. In conventional medicine the accepted respiration rate a healthy person takes during that minute is 10 to 12, with each breath drawing in a volume of 500 milliliters of air, for a total volume of 5 to 6 liters in one minute

IX. **Fraction of Inspired Oxygen(FiO_2):** Fraction of inspired Oxygen concentration (FiO_2): This is a term used to describe Oxygen concentration of the air that is entering your airway and been deliver to our alveoli. now the aim of the oxygen therapy is to increase the FiO_2, thereby increasing the oxygen concentration in your alveoli. Concentration of oxygen within the alveoli and hence making sure that more of it passes down the concentration gradient into the blood for effective respiration.

Formula for Calculating Fio_2

FiO_2=

$$\frac{\text{NRB FlowxNRB O2 COnc}+(\text{Atm.FlowxAtm.O2 Conc}}{\text{Peak Inspiration Flow (PIF)}} \quad (4.3)$$

Where:

FiO_2 = Fraction of Inspired Oxygen

NRB Flow= Non Rebreather Mask Flow

NRB O_2 Conc.= Non Rebreather Oxygen Concentration

Atm. Flow= Atmospheric Flow

Atm. O_2 Conc. = Atmospheric Oxygen Concentration.

5. Conclusion

The design, production and testing of an Automatic Valve-bag resuscitator yielded the expected results in table 4.2. acceptable in the conventional medical practices.

There is a dire need for oxygen therapy in every Nigeria healthy facility (Hospital). And this research work is to serve as an integral equipment to boost the performances of hospitals when produced in large quantity. “Any work about availability of Oxygen is always great news” (Josiah, 2022).

DECLARATION

The authors hereby declared that there is no conflict of interest with regards to this research work, authorship, and/or publication of the article. Information for this research would be available upon request.

ACKNOWLEDGMENT

A big thanks to the Department of Mechanical Engineering, University of Port Harcourt, Nigeria, where the design, construction and testing took place.

REFERENCES

Aliveneta. (2022). DC Motor. *Electrical Material*. Retrieved from http://www.aliveneta.it/genesis-battery-13a

Bible, H. (1200 BC). *Kings 2.* HarperCollins Publishers.

British Medical Association. (2002). *Decisions about cardiopulmonary resuscitation model information leaflet.*

British Medical Association. (2010.). Children and young people tool kit. Retrieved from www.bma.org.uk/ethics

Center for Disease Control and Prevention. (2021). *Three Things You May Not Know About CPR.* U.S. Department of Health & Human Services. Source: National Center for Chronic Disease Prevention and Health Promotion , Division for Heart Disease and Stroke Prevention.

Data, W. C.-1. (2022). *COVID-19 CORONAVIRUS PANDEMIC.* Center for Disease Control. worldometer. Retrieved from https://www.worldometers.info/coronavirus/

Eisenberg, M. S. (2010). History of the Science of Cardiopulmonary Resuscitation. *Contemporary Cardiology: Cardiopulmonary Resuscitation*, 1-9.

Eisenberg, M. S., & Psaty, B. M. (2010). Cardiopulmonay Resuscitation. *Celebration and Challenges; Journal of American Medical Association*. doi:10.1001/jama.2010.898

Elam, J., & Safar, P. (1977). *Advances in Cardiacpulmonary Resuscitator.* new York: Springer-Verlage; New York Heidleberg Berlin.

Encyclopedia, M. E. (2007). *Artificial Respiration.*

Fischer, G. (2020). Ventilator Design and Assembly. *Pandemic Engineering*, part 1 of 2.

Jantti, H. (2010). Cardiopulmonary Resuscitation (CPR) Quality and Education. *Dissertation in Health Science*, 6-115.

Jevon, P. (2010). Advanced Cardiac Life Support: A Guide for Nurses. (D. J. Pooni, Ed.) *Cardiopulmonary Resuscitation: Standards for Clinical Practice and training*.

Jia, D. Y. (2005). *Nature of Mechanical Machine Design. INME 4012-LECTURE 1.*

Josiah, A. (2022). *Inteview for the Design, Production and Testing of an Automatic Valve-Bag Resucitator.* Verbal Communication, Kogi State Specialist Hospital, Intensive Care Unit, Lokoja.

Jude, J. R. (2003). Personal Reminiscences of the Origin and History of Cardiopulmonary Resuscitation (CPR). *American Journal of Cardiology, Volume 92,* (ISSUE 8,), P956-963, . doi:https://doi.org/10.1016/S0002-9149(03)00977-9

KOUWENHOVEN, W. B. (1977). *Advances in Cardiopulmonary Resuscitator.* (J. E. Peter Safar, Ed.) Department of Anesthesiology/Critical Care Medicine, University Health Center of Pittsburgh, Pennsylvania: Springer-Verlag New York Inc.

Mabry, R. L., & Frankfurt, A. (2011). Advanced airway management in combat casualties by medics at the point of injury. *Journal of Special Operations Medicine*. Retrieved from https://en.wikipedia.org/wiki/Bag_valve_mask

Mcadams, R. (2008). *Learning to Breathe: The History of Newborn Resuscitation.* Glasgow: University of Glasgow Printing Press.

National Safety Patient Agency. (2004). http://www. npsa.nhs.uk/patientsafety/alerts-and-directives/alerts/crash-call/ Accessed 11 January 2023. *NSPA*.

NHS Scotland. (2010). Resuscitation planning policy for children and young people under 16 years Children and Young People Acute Deterioration Management t (CYPADM). (S. Government, Ed.)

Nickson, C. (2020, Nov 3,). Life in the Fast lane. Retrieved from https://litfl.com/bag-valve-mask-bvm-ventilation/

Nolan, J. (2005). *European Resuscitation Council Guidelines for Resuscitation .*

Odor Godwin E, E. C. (2022, December 6). BOLT Therapy, an wholesome Breathing Volume Restoration;. *A Panacia to Asthma, Snoring and other asphyxia*.

Potchileev, I., Doroshenko, M., & Mohammed., A. N. (2021, August 1). Positive Pressure Ventilation. *National Center for Biotechnology Information*.

Prakash. (2015). *A Research Proposal on Development.* Retrieved February

Royal College of Anaesthetists,. (2008). *Cardiopulmonary Resuscitation: Standards for Clinical Practice and*

Training. A Joint Statement from The Royal College of Anaesthetists, The Royal College of Physicians of London, . London: The Resuscitation Council (UK).

Stathis Avramidis. (2012). *Facts, Legends and Myths on the Evolution of Resuscitation.*

Sullivan, D. (2022). *Cardiopulmonary Resuscitation (CPR).* Healthline. Retrieved from https://www.healthline.com/health/unconsciousness-first-aid

Winters, M. E., Bond, M. C., DeBlieux, P., Marcolini, E. G., & Woolridge, D. P. (2017). *Emergency Department Resuscitation of the Critically Ill* (2nd ed.). Dallas Texas, USA: American College of Emergency Physician; Advancing Emergency Care.

Zoll, P. M. (2002, January). Early History of Cardiac Pacing and Defibrillation. *Indian Pacing and Electrophysiology Journal, 1*(2), 2–3.

APPENDIX A: ARDUINO CODE

The following are the Arduino Nano programming codes of the device circuits for the functionality of the resuscitator

```
#include <LiquidCrystal_I2C.h>        // INCLUDING THE I2C LIBRARY
#define USE_ARDUINO_INTERRUPTS true    // Set-up low-level interrupts for most acurate BPM math.
#include <PulseSensorPlayground.h>     // Includes the PulseSensorPlayground Library.

//  Variables
const int PulseWire = 0;       // PulseSensor PURPLE WIRE connected to ANALOG PIN 0
int motorA = 8;//Define motor driver pins
int motorB = 10;
int Threshold = 700; //Setting threshold for pulse sensor

int lcdColumns = 20; // deining number of columns for LCD type
int lcdRows = 4; // Define number of rows for LCD


LiquidCrystal_I2C lcd(0x3F, lcdColumns, lcdRows);  // LCD SET UP AND I2C ADDRESS
PulseSensorPlayground pulseSensor; // SETTING UP PULSE SENSOR
```

```
void setup(){
  // initialize LCD
  lcd.init();
  // turn on LCD backlight
  lcd.backlight();
  pulseSensor.analogInput(PulseWire);
        //auto-magically blink Arduino's LED with heartbeat.
  pulseSensor.setThreshold(Threshold);

  // Double-check the "pulseSensor" object was created and "began" seeing a signal.
   if (pulseSensor.begin()) {
     //This prints one time at Arduino power-up,  or on Arduino reset.
  }
  // SET UP PIN CONFIGURATION FOR ALL COMPONENTS
  pinMode(motorA, OUTPUT);
  pinMode(motorB, OUTPUT);
  pinMode(A2, INPUT);
  pinMode(A3,INPUT);
```

```
  Serial.begin(9600);// INITIALIZING SERIAL MONITOR


}
```

```
void loop(){
  // set cursor to first column, first row

 int myBPM = pulseSensor.getBeatsPerMinute();// "myBPM" hold this BPM value now.

if (pulseSensor.sawStartOfBeat()) {
  lcd.clear();// Constantly test to see if "a beat happened".
 lcd.setCursor(0,0); // If test is "true", print a message "a heartbeat happened".
 lcd.print("PULSE: " + String(myBPM));                        // Print phrase "BPM: "
                       // Print the value inside of myBPM ON LCD.
}

  int val2 = analogRead(A3);//INITIALIZING BATTERY VOLTAGE SENSOR
  int out2 = map(val2, 0,848, 0, 100); //MAPPING VALUES


Serial.println(out2);
```

Mr. Odor Godwin Ekunke, had his BEng degree in Mechanical Engineering from the University of Port Harcourt in 2017. He is a talented CAD/CAM Designer, a systematic Tutor of Computer Aided Design and Manufacturing Software such as AutoCAD & Solidworks with over 5 years of cognate experience. In 2020, He re-designed a Face shield Frame, reduced its 3D printing time from 1.30hour to 45mintues for the University of Port Harcourt Covid-19 Africa Response Team using Solidworks software, he helped the team achieved their face-shield production goals in a far exceeding manner. In 2019 He was awarded a Petroleum Technology Development Fund (PTDF) MSc Local Scholarship for his Master's degree in Mechanical Engineering (MEng), with area of specialization in Industrial and Systems Engineering (ISE) in the University of Port Harcourt. Mr. Godwin E. Odor worked as a CAD Designer at Frazimex Engineering Ltd Port Harcourt Nigeria in the Technical Safety Department as a Graduate Trainee in 2020/21. And he works currently with Dangote Cement Plc Obajana Kogi State, Nigeria as Draughtsman while combining these engagements with his Post Graduate Studies at the University of Port Harcourt Nigeria.

Dr. Celestine Ebieto Ebieto had his BEng degree in Mechanical Engineering from the University of Port Harcourt in 2007. After graduation, being the best graduating student in Mechanical Engineering, he was offered automatic employment as a graduate assistant. He went on to pursue his MEng degree also in Mechanical Engineering with a specialty in Thermofluid Engineering. He was appointed a full lecturer, Mechanical Engineering in 2011. He was awarded his PhD Mechanical Engineering from the University of Sheffield, United Kingdom in 2018. His thesis was on dynamics of premixed flames in tube. His research was particularly on the dynamic characterization of alternative fuels for combustion engines. During his PhD studies, he took a short course on alternative fuels and subsequently worked part-time at the Low Carbon Combustion Centre, University of Sheffield. His research areas are in Engine Combustion, Laminar and Turbulent premixed combustion, Alternative Fuels, PM and Gaseous Emissions, Heat Exchange Processes, Fluid Flow Measurement, Modeling of Energy Systems, and Low Carbon Energy Systems. His work is predominantly experimental but uses CFD and analytical techniques. Dr. Celestine teaches Principle of Automotive Engineering, Automotive Engineering, Vehicle Dynamics, Fluid Mechanics and Turbomachinery. He is an associate fellow of the Higher Education Academy, UK (AFHEA). He is currently the Coordinator of the Faculty of Engineering E-Library and the Examination Officer in the Department of Mechanical Engineering, University of Port Harcourt, Nigeria.